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ERROR STATISTICS AND CODING FOR BINARY TRANSMISSION OVER TELEPHONE CIRCUITS

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INTRODUCTION

Commercial transmission of digital data over telephone circuits is capable of providing an overall error probability on the order of 10^{-5}, but in many situations, lower error probabilities are either needed or highly desirable. This paper will enquire whether coding can be efficiently combined with existing digital data systems to provide these lower error rates.

The applicability of coding, however, is very closely related to the particular statistics with which the errors occur. For instance, a simple single error-correcting block code would be quite effective if the errors were independent in time, but almost useless if the errors were to occur clumped together into bursts. Likewise, there are simple burst error-correcting codes* that are very effective for errors clumped together into short bursts, but such codes are almost useless if an appreciable number of bursts, or noisy periods, persist for many digits. In fact, even the most advanced error-correction schemes are not very effective if there are noisy periods lasting for hundreds or thousands of digits since the capabilities of such schemes are overloaded during the noisy periods and wasted at other times. As will be shown later, a simple and effective alternative in such situations is to use coding to detect the presence of errors in a block and then re-transmit blocks with errors.

Experimental measurements capable of resolving these questions about error statistics have been made for some time. One technique[2,5] developed at Lincoln Laboratory, is to transmit a 16-symbol message, compare the received message with that transmitted and punch onto paper tape pertinent error data if the transmitted and received messages do not agree. The paper tape is then processed to determine several quantities such as the average error rate, the variation in error rate as a function of the day of the week or the time of the day, and the distribution of errors within the 16-symbol words.

This type of analysis indicated that the errors on digital data telephone circuits are not independent, but it left unanswered the question about the distribution of the duration of noisy periods. About 2000 hours of this data have been re-analyzed in this report in order to answer this question. The analysis of these data will be given in the next section and then the implications to coding will be discussed.

EXPERIMENTAL NOISE DATA

The noise data[3,6,7,9] that were used in this report were obtained using four different data systems: CTDS, Milgo, A-1 and Kineplex. The types of telephone line and amount of time over which the data were taken are tabulated in Table I. The lines used were private lines leased from the New England Telephone and Telegraph Company. The lines received no special treatment or equipment and are expected to be typical of the private wire plant. A detailed account of the actual days and run numbers that were used is in the Appendix.

* See Peterson[10] for discussion and bibliography on burst codes.

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The recording of the error data was accomplished with the ADDER[2,5] (automatic digital data error recorder). The pattern of ones and zeroes in the transmitted word was determined by toggle switch settings and was usually kept constant during a day's run but was varied from one day to the next. When errors occurred, the ADDER punched the received word and time of occurrence onto paper tape. Since the time required to punch the necessary data for a received word containing errors is approximately thirty times longer than the time required for transmission (assuming the 1300 bit/sec rate), some provision is necessary to handle successive words with errors. The ADDER has storage for three 16 symbol words. If words with errors are received when these three storage registers are in use, a counter, called the "excess error" counter, is used to count the number of such words even though the words cannot be saved. When a storage register is again available for error data, the contents of the "excess error" counter are punched onto tape and the counter is reset to zero.

Successive 16 symbol words were combined into longer sequences of 127, 255 and 511 symbols which will be called code words. Several error statistics of the longer sequences were then computed. These lengths were chosen to fit the length requirements for the Bose-Chaudhuri[1] class of cyclic codes. The lengths of the code words differ by one from a multiple of 16 and in forming the code words, this extra symbol was ignored. If an "excess error" count occurred in forming the longer sequences, the last recorded 16 symbol error pattern was repeated immediately in the longer words as many times as indicated by the counter.

The following error statistics were measured for the code words:

1. The distribution of the number of errors in code words that have errors
2. The distribution of burst lengths* in code words that have errors
3. The distribution of the number of 16 symbol words with errors in code words that have errors
4. The distribution of the number of code words from one code word with errors to the next code word with errors.

The results of these four measurements for the CTDS data system using code words with lengths 127, 255 and 511 are shown in Figures 1 through 4. Continuous curves are drawn through the data points to indicate the general trend of the data even though more accurate representations would have been the usual stair-step curves for discrete distributions. In Figures 5 and 6 the distribution of errors and burst lengths for code words with 511 symbols is shown for the four data transmission systems that were used.

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* The "burst length" is defined here as the number of symbols from the first to the last symbols in error in any given code word. Thus the minimum burst length for a code word in error is one and the maximum is the length of the code word.

DISCUSSION OF NOISE DATA

The figures clearly indicate that the errors occur in bursts rather than independently. The average probability of a symbol error in the telephone line channel is about 10^{-5}.[3] If these errors were independent then, for word lengths of 511 symbols, words with single errors would account for 0.997 of all the words with errors instead of 0.21 as in Figure 1. It should be noted that the error data shown in Figures 1 through 4 are nearly independent of the length of the code. Thus if error correction is used to correct errors in 90 per cent of the code words with errors, the code must be capable of correcting up to 30 randomly placed errors independent of whether a 127 or 511 symbol code is used. Although the individual curves differ considerably when the data system is changed as in Figures 5 and 6, they still illustrate the same characteristics of the noise. It is also to be observed from the numbers of 16 symbol words with errors in code words with errors in Figure 3 that there are many instances in which errors are spread throughout the code word rather than being confined to one or two short severe bursts.

One additional characteristic of the data should be discussed. There was evidence in some of the data of complete loss of signal as though the line were momentarily open or as though the signal suffered from severe fading. Although the actual time such conditions prevailed was very small, the curves in Figures 1 through 6 would be noticeably affected by including these data since a large number of errors are involved. For example, the signal was lost during 0.65 minute of one of the Milgo records. The data collected during this time would result in 76 code words with errors which is more than 10 per cent of the errors found in the remaining 448 hours of noise measurement. Consequently noise data obtained when a complete loss of signal was apparent were removed from the data used in Figures 1 through 6, and this amounted to 0.65 minute for the Milgo system and 4.30 minutes for Kineplex.

Complete line failures of this type usually result in a received word with all zeroes or all ones depending upon the modulation system which is used. These failures are easily detected by the decoder by requiring that all transmitted words contain a minimum number of ones (or zeroes). For example, if an open line results in the all zero sequence at the receiver, complementing the parity check symbols after they are computed would insure that the all zero sequence is not a code word for now all zeroes in the information places will result in all ones in the parity places.

ERROR CORRECTION

In addition to characterizing the noise, the curves are also useful in forming conclusions about the use of error-correcting codes for telephone circuits. A number of error-correcting codes and decoding procedures are available for binary channels and an important question is whether or not these codes are practical in combating the noise found in telephone circuits.

For a specific example, consider the 546 hours of data for the CTDS system which represents a total of 5×10^6 code words of length 511. Of these only 1475 (less than 1 out of every 3000) contained errors. Assume that an error-correcting code is used to reduce the number of code words containing errors by a factor of 10. This would require that the code correct 90 per cent of the words that have errors, or from Figure 1, that the code correct all code words containing up to 30 errors. Since the uncorrected words contain so many errors, even such a code would reduce the number of symbol errors by a factor of less than 2. The amount of equipment to correct 30 errors with present-day decoding techniques would prohibit the use of such a code with telephone circuits except perhaps for some very unusual applications. Even if the error correction were done, a considerable amount of redundancy would be required in the transmitted code word. Although an optimum code capable of correcting up to 30 errors in a block of 511 symbols is not known, the theory of error-correcting codes guarantees that at least 161 of the 511 symbols would have to be parity checks. If a burst error-correcting code were used under the same assumptions, it would have to be capable of correcting a burst of up to 300 symbols which is also unrealistic.

Any conclusion about the feasibility of error-correcting codes with telephone circuits must be prefaced by repeating again that the curves represent 2000 hours of data taken over several private telephone lines with four types of modulation equipment. Improvement in either the noise characteristics of the telephone lines or in the modulation equipment may affect the conclusion. However, subject to the foregoing reservations, error-correcting codes in general do not appear practical for use with telephone circuits because their cost is too great in relation to the number of code words with errors that would be corrected.

ERROR DETECTION

Since error-correcting codes appear impractical for telephone circuits, the question of whether redundancy of any type is useful and practical and whether there are other schemes for correcting errors arises and will be discussed.

It is easy to envision communication systems in which the receiver is willing to discard data containing errors but is unwilling to tolerate errors in the data that is accepted. It will be shown that for applications such as these, the addition of very small amounts of redundancy can reduce the probability of an undetected error almost to zero. In other communication systems there may be equally stringent conditions on accepting only error-free data, but it may be possible to signal the transmitter to re-transmit the message if errors are detected. In situations such as these, error-detecting codes can be very useful. In general, error-detecting codes can be implemented very easily with a minimum of equipment and for the same probability of undetected error require much less redundancy than error-correcting codes. The noise in telephone circuits lends itself to error detection very well. The channel seems to operate in two extreme states: noise-free and very noisy, and about all that can be done from a practical viewpoint if reliable communication is required is to use the channel when it is good and not use it when it is bad. The experimental noise data were used with several error-detecting codes which were simulated on the 709 computer. These results will be presented after a brief description of the codes and their implementation.

One promising class of new codes for error detection is the class of cyclic codes. These are systematic group codes in which a sequence of k information symbols are encoded into a sequence of n symbols by appending n-k redundancy symbols. Cyclic codes can be encoded with an n-k stage shift register and if only error detection is required, the decoding also can be done with an n-k stage shift register.

The encoding and decoding equipment are shown in Figure 7. A square box represents a single stage shift register and a circled plus sign represents addition modulo two. Encoding is done as follows:[10]

1. With the shift register initially set to all zeroes and switches S_1 and S_2 in the positions shown, the k information symbols are fed into the shift register one at a time and simultaneously transmitted over the channel.

2. After the last information symbol has entered the shift register, the shift register contains the n-k redundancy symbols. Switches S_1 and S_2 are now placed in the opposite positions and the contents of the shift register are transmitted over the channel to form the code word with n symbols.

The decoding for error detection is performed in much the same way.

1. With the register initially set to all zeroes and switch S_1 closed, the entire n-symbol received word is shifted into the register one symbol at a time.

2. After the last symbol has entered, a test is made of the contents of the register and an error is assumed to have occurred unless every stage contains a zero.

Bose-Chaudhuri codes were selected for use with the experimental noise data. These are cyclic codes with the following properties. For any positive integers m and t there is a Bose-Chaudhuri code with length $n = 2^m - 1$ for which the minimum distance* between any pair of code words is at least $2t+1$. The number of parity check symbols is never greater than mt. The combinations of length, minimum distance and number of parity checks which were used are tabulated in Table II.

The Bose-Chaudhuri codes with minimum distances three and five are close packed[4] and hence are optimum when used for error correction with a symmetric, independent channel. The structure that these codes must have to be optimum when used for error correction should make them good codes for error detection, and in fact, for a given code size, no greater minimum distance can be achieved with any fewer parity checks.

Any code with minimum distance $2t+1$ will detect any 2t or fewer errors that occur. In addition, when a cyclic code with r parity checks is used for error detection, all error bursts of length $r-1$ or less are detected. The only way for an undetected error to occur is for noise to alter the transmitted word in such a way that the received word is identical to some other code word. This is possible only if more than 2t errors or a burst of r or more symbols occur, and even then, the probability that the errors will be undetected can be extremely small.

* The distance between two binary sequences is equal to the number of positions in which the two sequences differ.

An exact determination of the probability of an undetected error is difficult for it involves a determination of the probability of an undetected error for the individual code words. A reasonable simplification is to assume that when over 2t errors occur or when an error burst of r or more symbols occur, the code words and noise are essentially independent. Since there are 2^k code words and 2^n possible received words, the probability of an undetected error in such cases is approximately 2^{-n+k}. With these assumptions, the probability of an undetected error is now equal to the product of the probability that the received word has more than 2t errors or an error burst of r or more symbols by the probability that such a received word is a code word.

To illustrate the above, consider the CTDS data which represents 546 hours of ADDER operation. When 511 symbol code words were formed from the 16 symbol code words, a total of 1475 code words contained errors. Of these, 714 contained four or fewer errors. A Bose-Chaudhuri code with $n = 511$ and $n-k = 18$ has a minimum distance of five so that all of the 714 errors were detected. If the probability of an undetected error for error patterns with more than four ones is assumed to be 2^{-18} as mentioned above, one would expect that since 761 code words had more than four errors in 546 hours of operation, an undetected error would occur on the average of once every $2^{18} \times 546/761 = 1.87 \times 10^5$ hours of operation or once every 21.3 years. Similar results were obtained using other data systems, and these results are tabulated in Table II. When a $n = 127$, $n-k = 7$ code is used with the CTDS data, an undetected error is expected every 50 hours of operation. Actually 10 undetected errors occurred, or one every 55 hours of operation, which is in good agreement with the expected rate.

FEEDBACK

In many communication systems it is unacceptable for the receiver to know merely that there has been an error in a block of messages; the receiver must also be able to find the correct message. If a noiseless return channel, or feedback channel, is available from the receiver to the transmitter, the receiver can simply request a re-transmission of the offending message from the transmitter. Complications arise, however, if the feedback channel is noisy. Effective methods to handle a noisy feedback channel have been proposed by Metzner and Morgan[8] and by Wozencraft and Horstein[11].

The fundamental characteristic of all these methods is that the transmitter re-transmits the message both when the feedback signal is a request for re-transmission and when the feedback signal is in doubt. Thus a particular block of messages will fail to be correctly received only when there is an undetected error in either the forward or feedback directions. However, as described before, the probability of an undetected error using coding can be made as small as desired in both channels.

A much more likely event than an undetected error is that the same message will be correctly received several times due to detected errors in the feedback link. Metzner and Morgan[8] suggest handling this problem by means of an alternating tag on successive messages and there are also other procedures that can be used.

The use of feedback in communication generally causes some loss in rate over and above that lost by coding. In the case of telephone circuits, however, the rate loss due to repetitions is quite small. Assuming that both forward and feedback channels have similar characteristics as the data in this report, it should be necessary to repeat less than 1 block in 1500.

If such a feedback scheme is to be used with a constant data rate source, considerable storage is needed to handle the waiting line created by the occasional re-transmission of messages. However, if one considers a telephone circuit to be a channel with time-varying capacity, and notes from the data in Figure 1 that the capacity occasionally drops to practically nothing for periods longer than 500 digits, then one sees that considerable storage is required by any scheme that transmits reliably over such a channel.

To keep the waiting line from building up with a constant data rate source, it is necessary to have the source rate somewhat lower than the transmitter rate. The smaller the rate sacrifice here, the larger the storage that has to be provided. The storage can be of the fixed access type, but still it will constitute the major cost of the coding system. It is possible, although it appears unlikely, that a small amount of error correction in this situation could reduce the storage requirement enough to be economically feasible. In the situation where the source rate is controllable, however, the argument is very clear in favor of simple error detection and feedback, since little storage is necessary.

To illustrate the effect of attempting some error correction along with detection for telephone data systems, consider the CTDS data. Out of the 1475 code words of length 511 recorded with errors, only 323 had single errors. In Table II it is estimated that a Bose-Chaudhuri code of length 511 with 18 parity checks will produce an undetected error on such data about once every 21 years. If this code is used for a single error correction plus detection, an undetected error will occur not only when the noise changes one code word to another code word, but also when it changes a code word into any of the 511 words at distance one from a code word. This would produce undetected errors at an estimated rate of once every 15 days. An extra 9 parity checks would be needed to decrease the undetected error rate to the previous value of once every 21 years. Thus the reduction in rate necessary to correct the 323 single errors is equivalent to a loss of 91,000 of the original 5 million code words. This loss of rate will aggravate the waiting line problem and although no data are available here, it does not seem likely that many of the 323 words with single errors occur during the very noisy periods when the waiting line gets long.

MATHEMATICAL MODELS FOR TELEPHONE CIRCUITS

In the preceding pages, a large body of experimental error statistics has been used to determine methods for decreasing the error probability on digital data links. A seemingly more elegant approach to this problem is that of using the data to construct a mathematical model of error statistics and then determining how to decrease the error probability in the model. This approach has been used in the past, often with quite misleading results, so it is worth pointing out the dangers and difficulties here.

In constructing a model, it is first necessary to separate the important characteristics of the data from the trivia. If this is not done with caution, however, these "trivial" occurrences will be precisely the occurrences that cause errors in any reasonably chosen coding scheme. For instance, one could measure the first and second order error statistics on a digital data link and decide to ignore both the higher order statistics and the second order statistics for lengths greater than 15 or 20 bits. A model constructed from this data would clearly illustrate the short bursts of the noise but would completely ignore the very long periods of low channel capacity that make error correction impractical.

A somewhat better model could involve a channel with two states; one noisy and one noise-free, along with a distribution function determining the time spent in the noisy state. Assuming an error rate in the order of 1/2 in the noisy state, one is forced to conclude after the reception of a small number of correct digits that the channel is back in the noise-free state. This model again illustrates the short severe bursts of noise, but fails to bring out the more moderate bursts of much longer duration. Both these models would indicate the effectiveness of burst error-correcting codes, whereas the actual data clearly indicates just the opposite.

The previous paragraphs do not imply that these models are completely inapplicable to telephone lines. Such simple models might be useful in learning how to improve both telephone lines and their digital data transmitters and receivers. Such models are certainly inapplicable to coding questions, however, due to the great sensitivity of coding to slowly varying channel characteristics.

One can easily visualize models that are broad enough to include most of the quantities of interest in coding studies. For instance, the channel could be considered as having two states again, but the noisy state could now be characterized by a distribution function over both the error rate and the duration of the noisy state. The attractiveness of using a model rather than direct data fades somewhat for a model this complex that still omits many important characteristics. The results of this paper would have been both difficult to derive and somewhat questionable if a model approach had been used.

CONCLUSIONS

The data demonstrate that error-correcting codes are impractical with the circuits and modulation systems that were tested. The fact that all of the systems and circuits behaved in a comparable manner and that over 2000 hours of operation is represented suggests that this conclusion might be extrapolated to most of the "private wire" plant.

On the positive side, it has been shown that error-detection codes either with or without feedback are practical. Using moderate size block lengths (100 to 500 symbols) and a very small amount of redundancy (15 to 20 symbols), it is possible to transmit over "private wire" telephone circuits with a probability of an undetected word error so small it almost can be neglected. Moreover, the encoding and decoding for such codes can be easily implemented with a modest amount of equipment most of which consists of a 15 to 20 stage shift register.

Modulation System	Channel Data Rate (Symbols/Sec)	Type of Telephone Line	Time (Hours)
CTDS	1300	Microwave	305
		K-carrier	241
A-1	1300	Microwave	521
Milgo	1000	Microwave	204
		K-carrier	249
Kineplex	2400*	Microwave	449
		K-carrier	118
		TOTAL	2087

* The error datawere recorded for only one channel of the Kineplex system. Data were transmitted but not recorded on remaining seven channels.[6]

Table I

Code Size			Error Data				
Length (Symbols)	Parity Checks (Symbols)	Minimum Distance (Symbols)	Data System	No. of Code Words	No. of Word Errors	Avg. time for Un-detected Errors (Years)	No. of Undected Errors Actually Found in Data
511	18	5	CTDS	5.0×10^6	1475	21.3	0
			Milgo	2.8×10^6	693	97.0	0
			Kineplex	1.4×10^6	1238	34.7	0
			A-1	4.8×10^6	2979	8.9	0
255	16	5	CTDS	10×10^6	1758	4.47	0
			Milgo	5.7×10^6	806	19.6	0
			Kineplex	2.4×10^6	1685	4.81	0
			A-1	9.5×10^6	4284	1.42	0
127	14	5	CTDS	2.0×10^7	2118	.895	0
			Milgo	1.1×10^7	908	3.53	0
			Kineplex	4.8×10^6	2659	0.541	0
			A-1	1.9×10^7	6405	.219	1
127	7	3	CTDS	2.0×10^7	2118	.0056	10

Table II

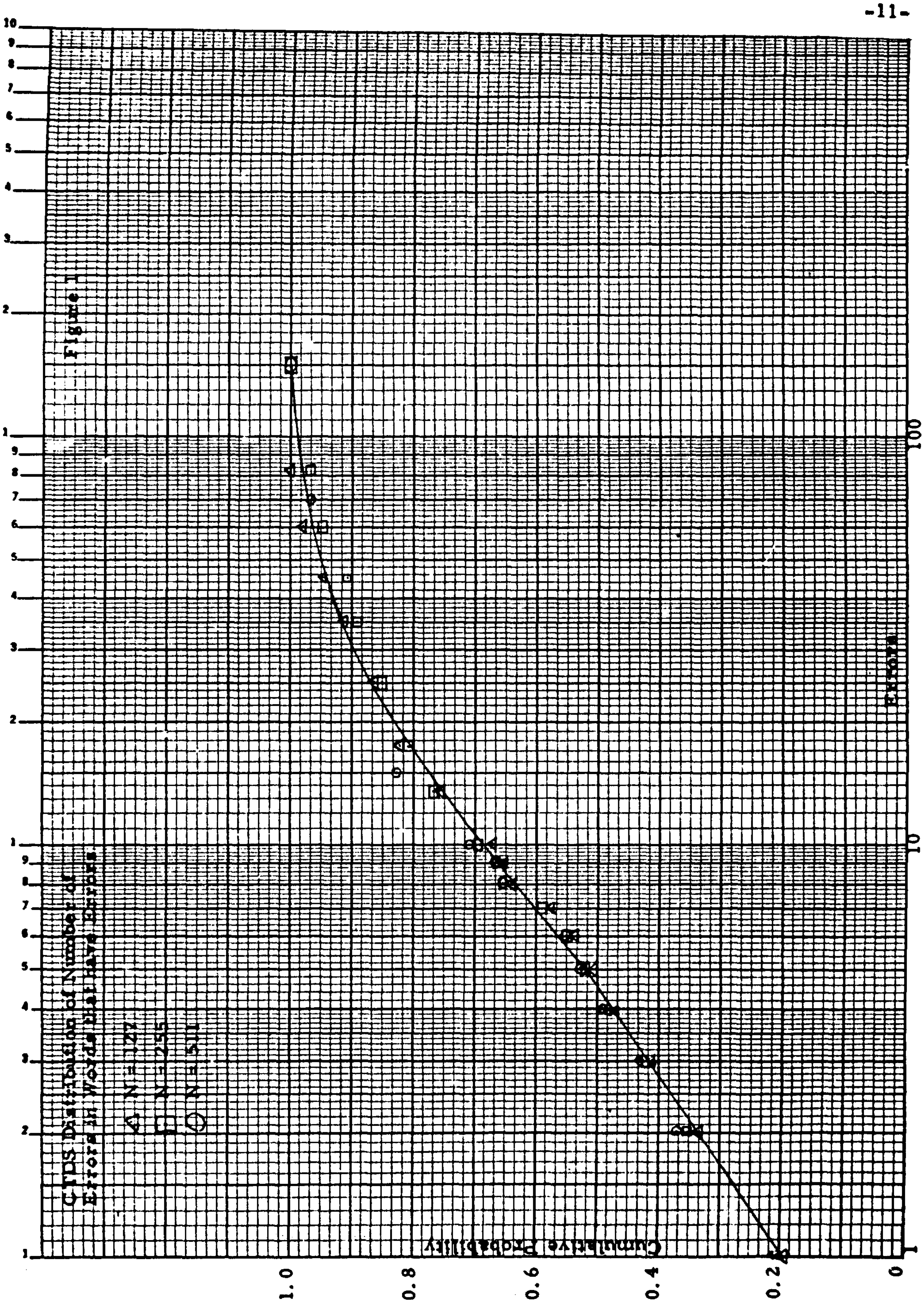


Figure 1
CTDS Distribution of Number of
Errors in Words that have Errors
N = 127
N = 255
N = 511
Errors
Cumulative Probability
1.0
0.8
0.6
0.4
0.2
0
1
10
100

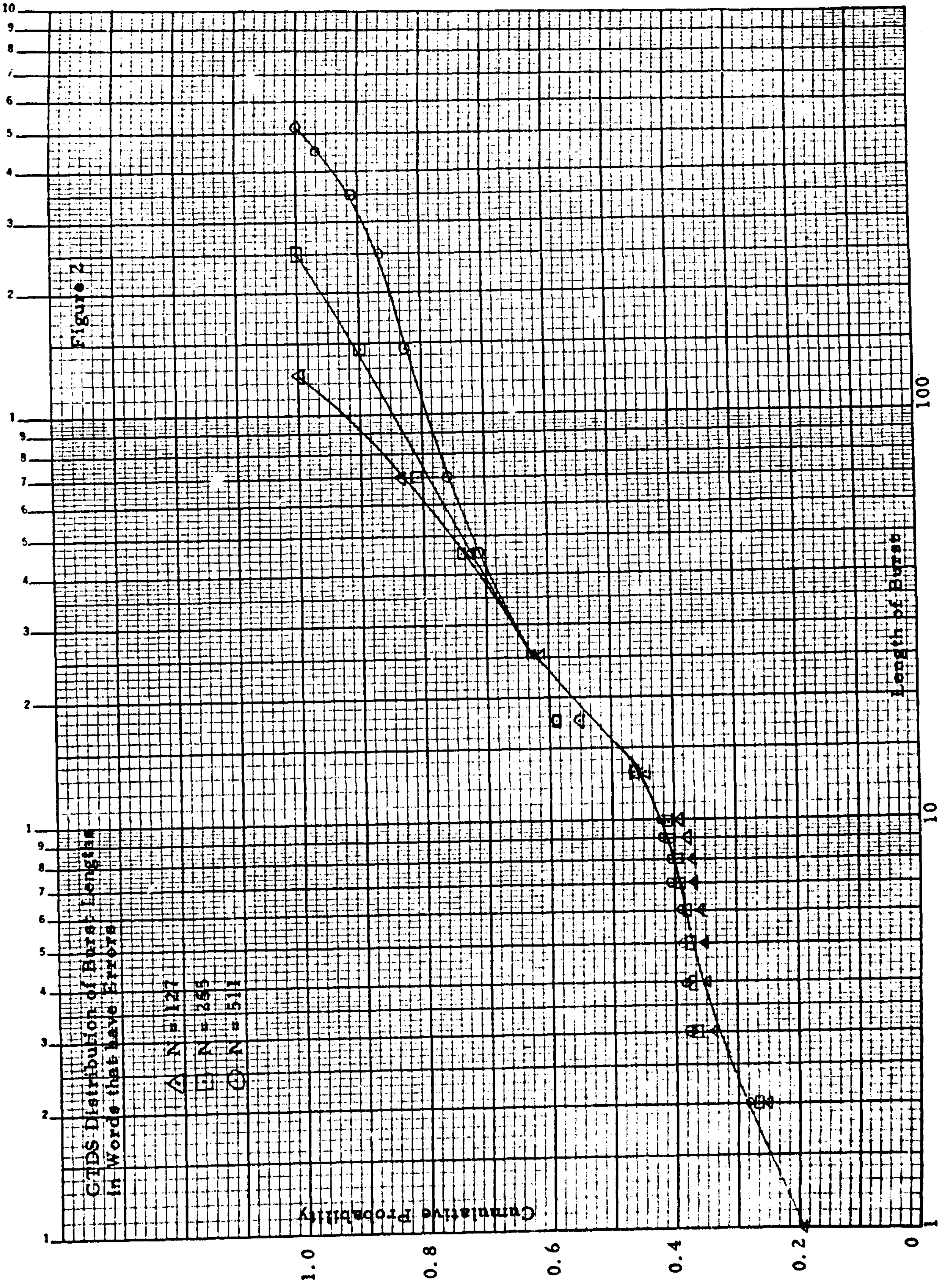
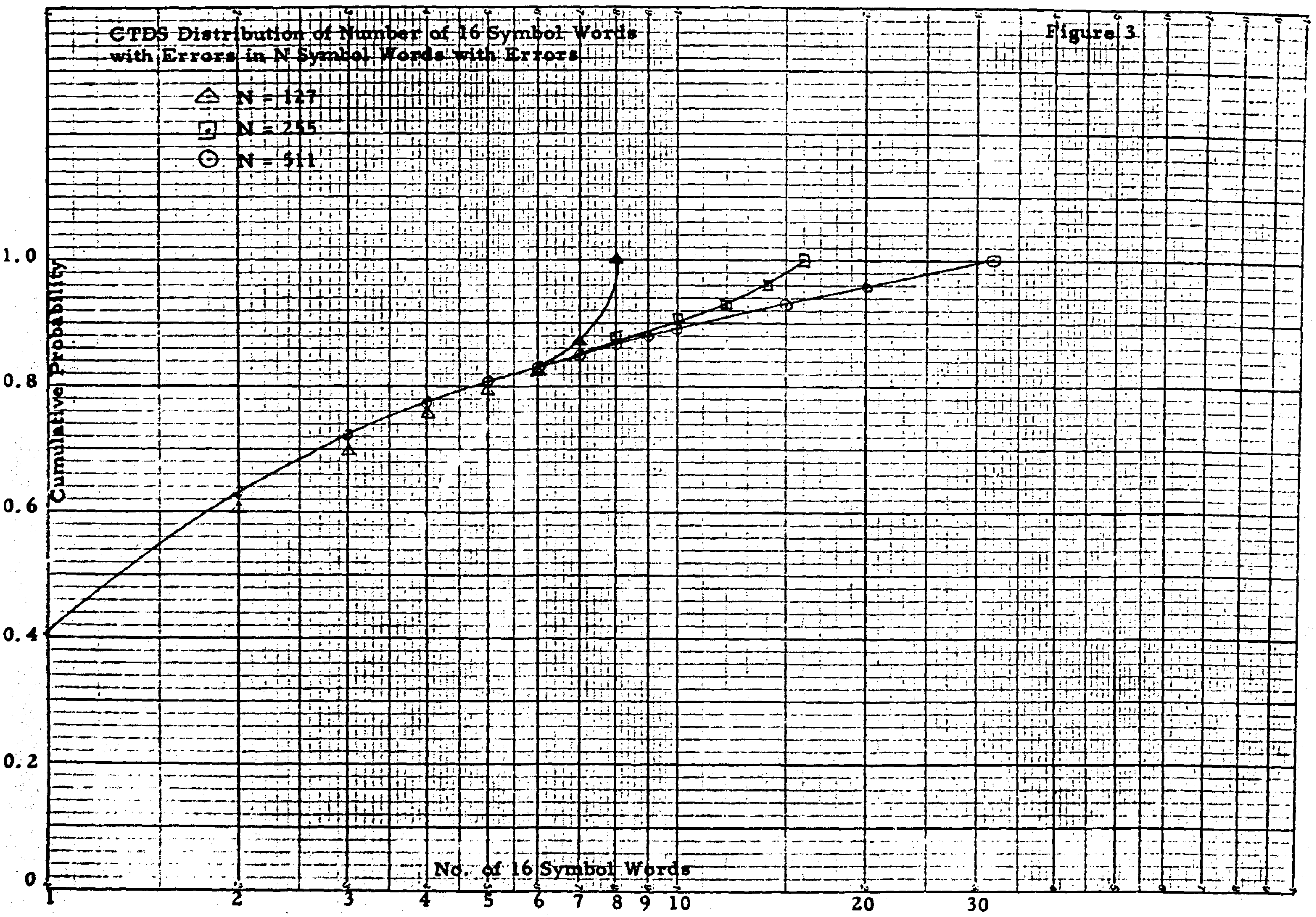
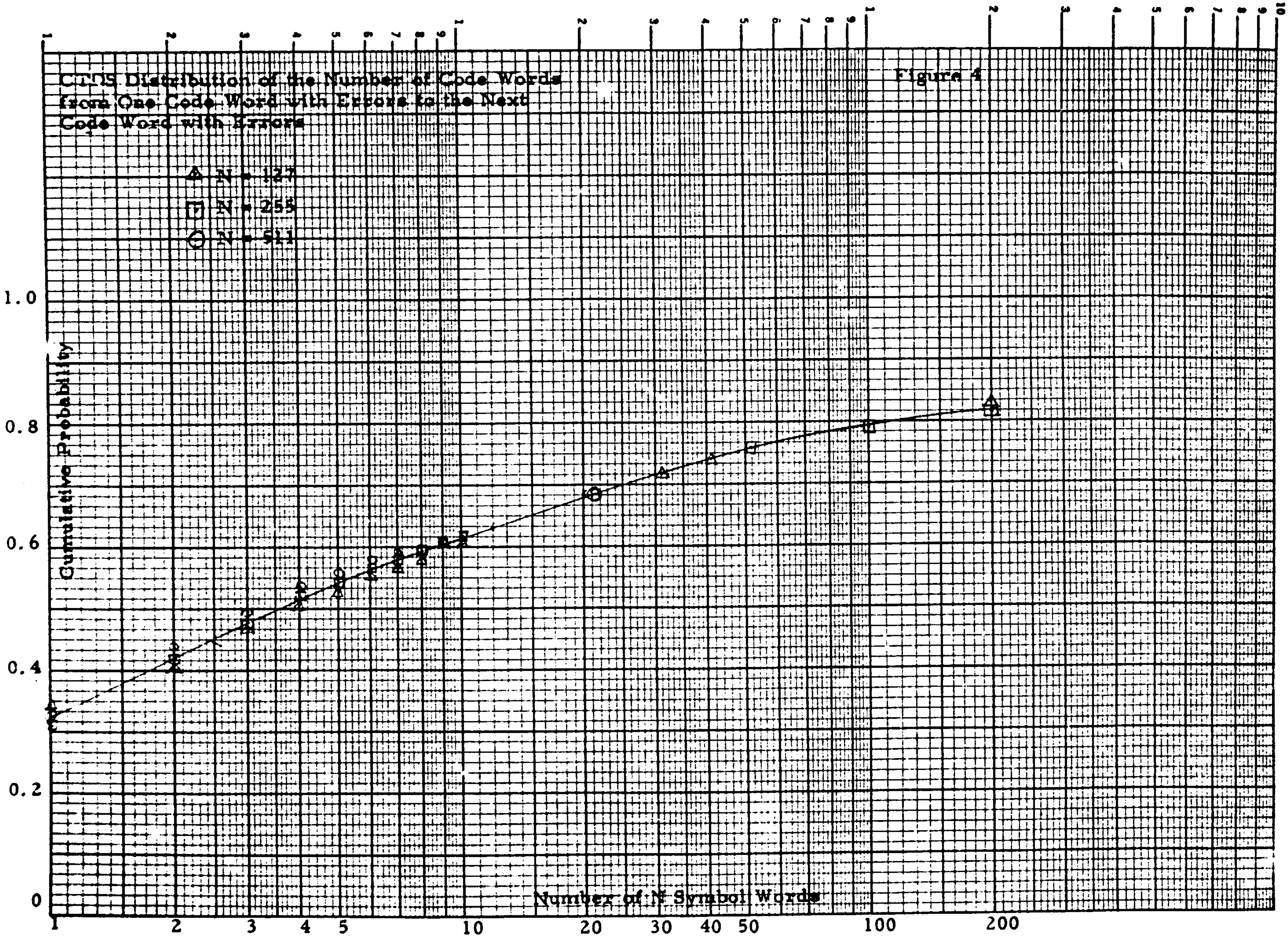
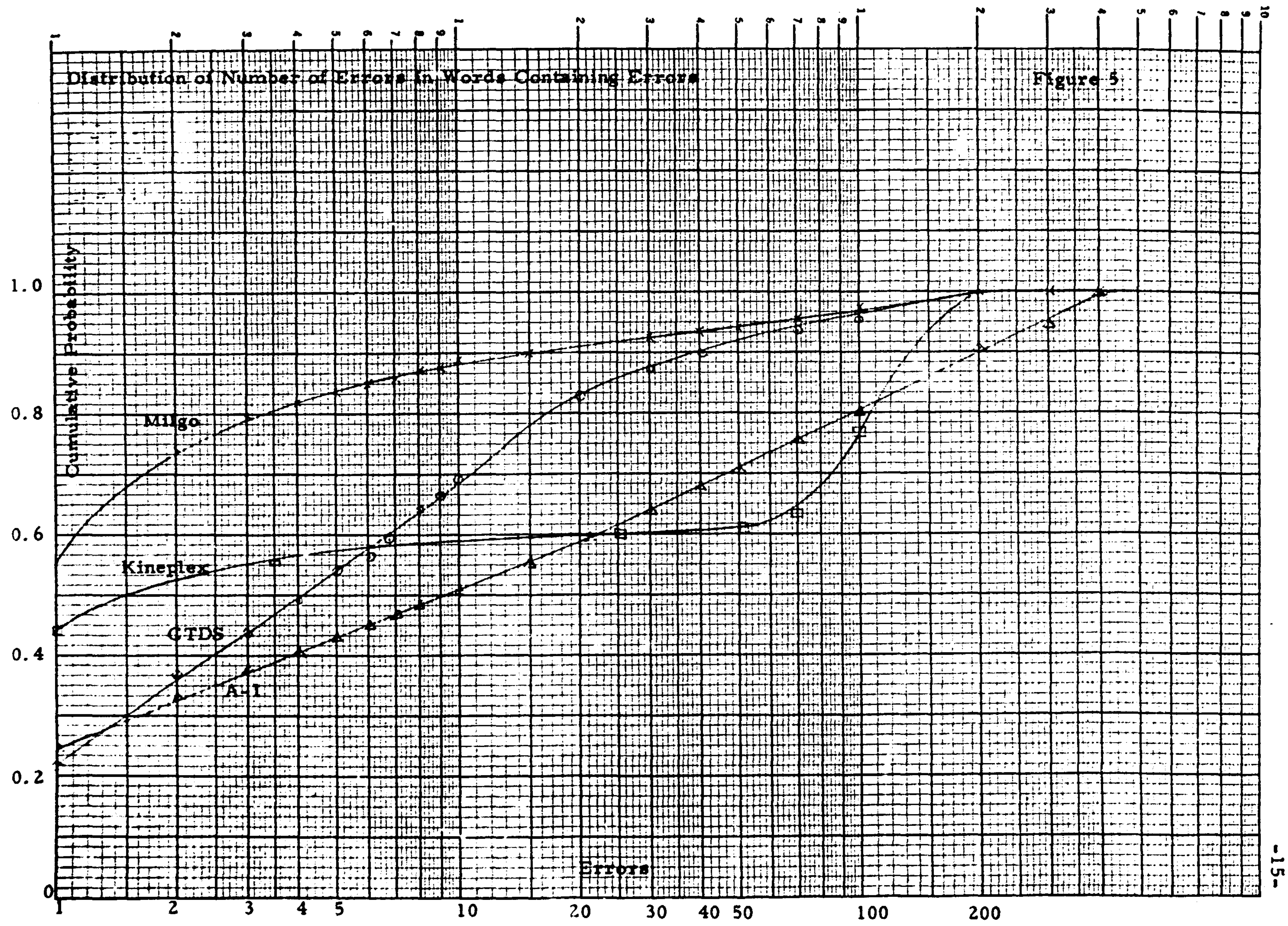

CIDS Distribution of Burst Lengths
in Words that have Errors
△ N = 127
□ N = 255
○ N = 511
Cumulative Probability
Length of Burst
1.0
0.8
0.6
0.4
0.2
0
1
10
100

Figure 2


CTDS Distribution of Number of 16 Symbol Words
with Errors in N Symbol Words with Errors
Figure 3
N = 127
N = 255
N = 511
Cumulative Probability
1.0
0.8
0.6
0.4
0.2
0
No. of 16 Symbol Words
1
2
3
4
5
6
7
8
9
10
20
30


CTDS Distribution of the Number of Code Words
from One Code Word with Errors to the Next
Code Word with Errors
Figure 4
N = 127
N = 255
N = 511
Cumulative Probability
1.0
0.8
0.6
0.4
0.2
0
Number of N Symbol Words
1
2
3
4
5
10
20
30
40
50
100
200



Distribution of Number of Errors in Words Containing Errors

Figure 5

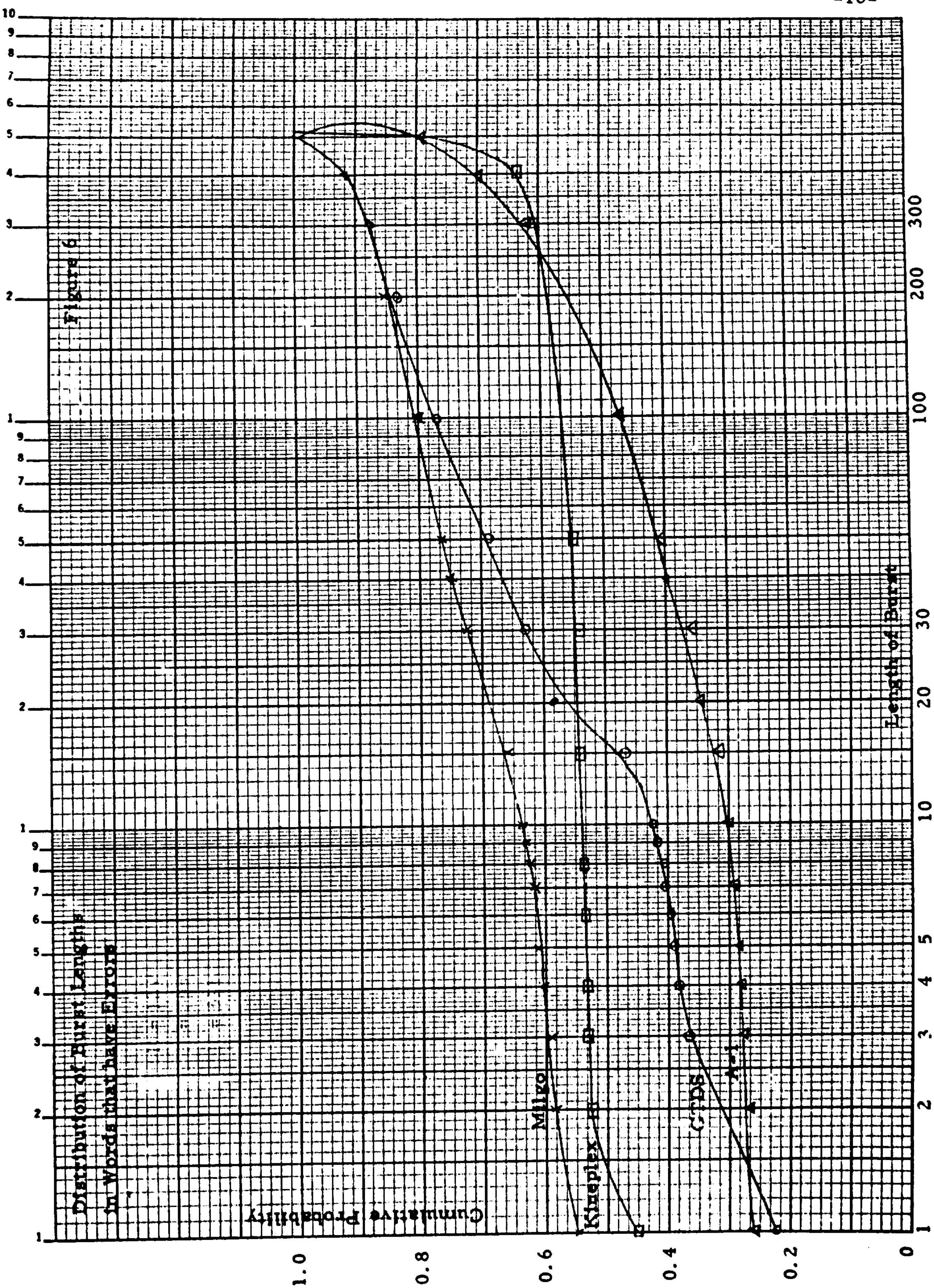


Figure 6

Distribution of Burst Lengths in Words that have Errors

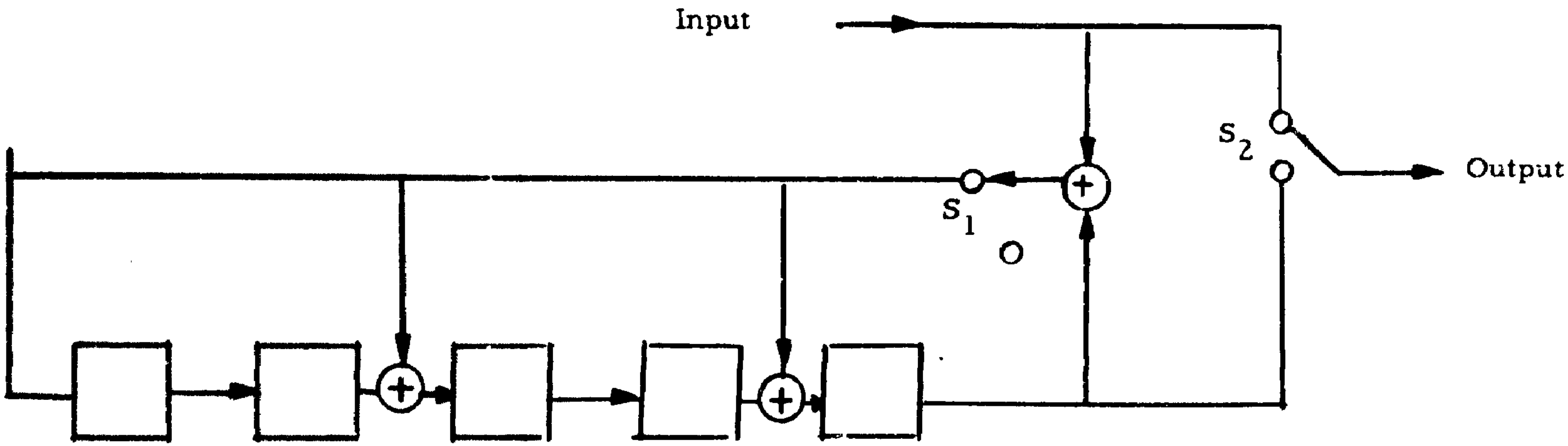


Fig. 7 Typical Encoder and Decoder for a Cyclic Shift Register Code.

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Appendix

Run Numbers and Days for the Error Data* Which Were Used

Run Number	Date	Line Type	Line Number
A1	4/11-12/60	Microwave	FD5755
A2	4/12-13/60	Microwave	FD5755
A5	4/15-18/60	Microwave	FD5755
A6	4/18-20/60	Microwave	FD5755
A7	4/20-21/60	Microwave	FD5755
A8	4/21-22/60	Microwave	FD5755
A9	4/22-23/60	Microwave	FD5755
A10	4/23-25/60	Microwave	FD5755
A11	4/25/60	Microwave	FD5755
A12	4/25-26/60	Microwave	FD5966
A13	4/26-27/60	Microwave	FD5966
A14	4/27-28/60	Microwave	FD5966
A15	4/28-29/60	Microwave	FD5966
A16	4/29-30/60	Microwave	FD5966
A17	4/30-5/2/60	Microwave	FD5966
A21	5/5-6/60	Microwave	FD5966
A24	5/9-10/60	Microwave	FD5966
A25	5/10-11/60	Microwave	FD5966

I. A-1 System

Run Number	Date	Line Type	Line Number
C1	2/24-25/60	Microwave	FD5965
C2	2/25-26/60	Microwave	FD5965
C3	2/26-29/60	Microwave	FD5965
C4	2/29-31/60	Microwave	FD5965
C6	3/7-8/60	Microwave	FD5965
C7	3/8-9/60	Microwave	FD5965
C9	3/10-11/60	Microwave	FD5965
C11	3/12-14/60	Microwave	FD5965
C12	3/14-15/60	Microwave	FD5965
C14	3/15/60	Microwave	FD5965
C15	3/17-18/60	Microwave	FD5965
C18	3/29/60	K-carrier	FD2423
C19	3/28-29/60	K-carrier	FD2423
C22	4/1-2/60	K-carrier	FD2423
C23	4/12-13/60	K-carrier	FD2423
C24	4/13-14/60	K-carrier	FD2423
C25	4/14-15/60	K-carrier	FD2423
C26	4/15-18/60	K-carrier	FD2423
C27	4/18-20/60	K-carrier	FD2423

II. CTDS System

* "Test Room Data Results," by E. J. Hofmann. Private communication.

Run Number	Date	Line Type	Line Number
K18	4/8-9/60	Microwave	FD5966
K19	4/9-11/60	Microwave	FD5966
K20	4/11-12/60	Microwave	FD5966
K21	4/12-13/60	Microwave	FD5966
K25	4/15-18/60	Microwave	FD5966
K26	4/18-20/60	Microwave	FD5966
K28	4/20-21/60	Microwave	FD5966
K29	4/21-22/60	Microwave	FD5966
K30	4/22-23/60	Microwave	FD5966
K31	4/23-25/60	Microwave	FD5966
K35	4/28-29/60	K-carrier	FD2423
K36	4/29-30/60	K-carrier	FD2423
K37	4/30-5/2/60	K-carrier	FD2423
K38	5/2-3/60	K-carrier	FD2423
K41	5/6-7/60	Microwave	FD5755
K42	5/7-9/60	Microwave	FD5755
K43	5/9-10/60	Microwave	FD5755

III. Kineplex

Run Number	Date	Line Type	Line Number
259	5/23-24/60	Microwave	FD5965
260	5/24-25/60	Microwave	FD5965
261	5/25-26/60	Microwave	FD5965
262	5/26-27/60	Microwave	FD5965
263	5/27-28/60	Microwave	FD5965
265	5/31-6/1/60	Microwave	FD5965
266	6/1-4/60	Microwave	FD5965
268	6/6-7/60	K-carrier	FD2423
269	6/8-9/60	K-carrier	FD2423
270	6/9-10/60	K-carrier	FD2423
271	6/10-13/60	K-carrier	FD2423
272	6/13-14/60	K-carrier	FD2423
273	6/14-15/60	K-carrier	FD2423
274	6/15-16/60	K-carrier	FD2423
275	6/17-20/60	K-carrier	FD2423

IV. Milgo